

Tuning mechanical and thermal properties of magnetron sputtered Zr–Hf–Cu metallic glasses

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Introduction

Magnetron sputter deposition as a non-equilibrium process with high cooling rates (higher than 10^6 K/s) is very suitable technique to prepare metallic alloys in an amorphous glassy state as thin-film materials. A short-range atomic ordering, based mainly on icosahedral clusters, in these materials gives rise to their exceptional physical and functional properties compared to their crystalline counterparts.

Results

Recently, we have shown that Zr–Cu thin-film alloys can be prepared as metallic glasses in a very wide composition range (30–65 at.% Cu) by non-reactive magnetron co-sputtering [1]. In the present study, we gradually substituted Hf for Zr and prepared three series of Zr–Hf–Cu thin films at approximately 45, 60 and 70 at.% Cu.

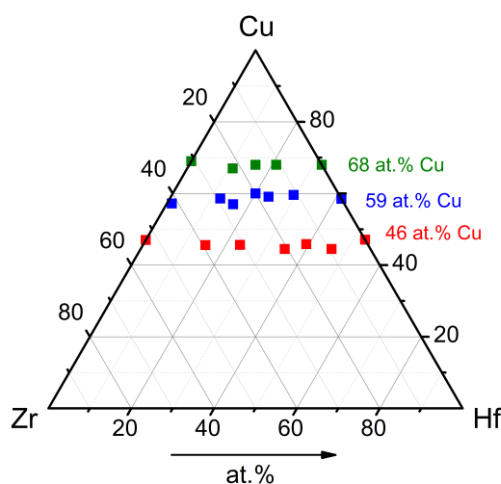


Figure 1: Elemental composition of the Zr–Hf–Cu thin films

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The films were deposited using three unbalanced magnetrons equipped with Zr, Hf and Cu targets in pure argon without an external heating. The magnetron with the Zr and Hf targets were operated in a dc regime while the Cu magnetron in a high-power impulse regime. The Zr, Hf and Cu contents in the films were controlled by adjusting the dc powers and the average target power in a period, respectively. The Zr–Hf–Cu thin films were analyzed by X-ray diffraction, energy dispersive X-ray spectroscopy, differential scanning calorimetry, micro- and nanoindentation, scanning electron microscopy and atomic force microscopy.

Mechanical properties and thermal behavior of binary Zr–Cu thin-film metallic glasses strongly depend on their elemental composition. A gradual growth of the hardness and crystallization temperature up to 70 at.% Cu was observed. Ternary Zr–Hf–Cu thin films prepared were X-ray amorphous and exhibited the glass transition. The substitution of Hf for Zr led to a monotonous increase of the hardness and the effective Young's modulus. We found that the evolution of mechanical properties correlates well with the evolution of the glass transition temperature and the crystallization temperature (Fig. 2). For the series with 45 at.% Cu, the hardness increased from 6.0 GPa to 7.3 GPa and the crystallization temperature from 452 °C to 524 °C. The increase of these quantities is supposed to be attributed to the change of the average bond energy in the amorphous Zr–Hf–Cu thin-film metallic glasses when substituting Hf for Zr.

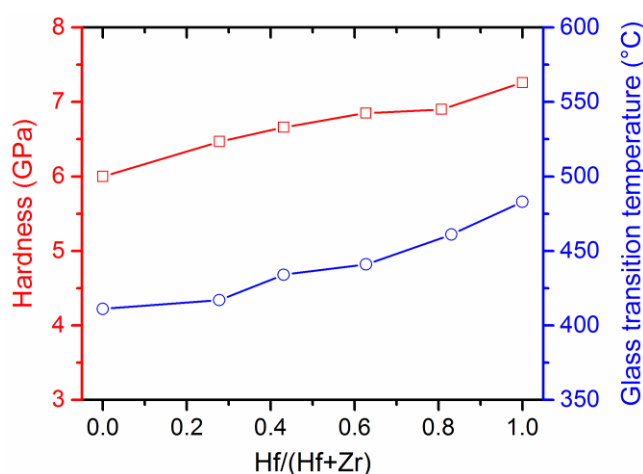


Figure 2: Hardness and glass transition temperature of the Zr–Hf–Cu thin films with approximately 45 at.% Cu

References

Zeman P., Zítek M., Zuzjaková Š., Čerstvý R. (2017) Amorphous Zr-Cu thin-film alloys with metallic glass behavior , *J. Alloys Compd.*, Volume 696, pp. 1298-1306.